

IAP5 Rec'd PCT/PTO 27 SEP 2006

## SEMICONDUCTOR DEVICE

## BACKGROUND OF THE INVENTION

## Field of the Invention

**[0001]** This invention relates to a semiconductor device that has a semiconductor chip connected in a flip chip manner.

## Description of Related Art

**[0002]** To realize a size reduction and high-density packaging of a semiconductor device, attention has been paid to a flip chip connection structure in which a semiconductor chip is connected to a solid state device while causing a functional surface of the semiconductor chip on which a functional element 54 is formed to face the solid state device.

**[0003]** FIG. 4 is a diagrammatic sectional view of a semiconductor device having a flip chip connection structure. This semiconductor device 51 includes a wiring board 52 and a semiconductor chip 53 connected to a surface 52a of the wiring board 52 while causing a functional surface 53a of the semiconductor chip 53 to face the surface 52a of the wiring board 52.

**[0004]** A rectangular connection pad 58 is formed on the surface 52a of the wiring board 52. The wiring board 52 and the semiconductor chip 53 are bonded and electrically connected together with a predetermined interval therebetween by means of a connecting member 55 connected to the connection pad 58. A solder resist film 56 that has a thickness smaller than an

interval between the surface 52a of the wiring board 52 and the functional surface 53a of the semiconductor chip 53 is formed on the surface 52a.

**[0005]** The solder resist film 56 has a rectangular opening 56a by which the connection pad 58 is exposed. As shown in FIG. 5, the opening 56a is greater in size than the connection pad 58 when viewed in plane. The connecting member 55 is connected to the connection pad 58 in the opening 56a.

**[0006]** A slight gap is formed between the surface of the solder resist film 56 and the functional surface 53a of the semiconductor chip 53. This gap is sealed with an underfill layer 57. The underfill layer 57 is formed such that the wiring board 52 and the semiconductor chip 53 are bonded together, and then a liquid underfill material is injected therebetween.

**[0007]** In more detail, after the wiring board 52 and the semiconductor chip 53 are bonded together, a dispenser 60 is disposed near the outer peripheral part of the semiconductor chip 53 as shown in FIG. 6A, whereafter a liquid underfill material 57P is poured between the surface of the solder resist film 56 and the functional surface 53a of the semiconductor chip 53 from the dispenser 60. Capillarity causes the underfill material 57P to enter and spread between the surface of the solder resist film 56 and the functional surface 53a of the semiconductor chip 53 as shown in FIG. 6B. When the whole area between the surface of the solder resist film 56 and the functional surface 53a of

the semiconductor chip 53 is filled with the underfill material 57P, the dispenser 60 stops discharging the underfill material 57P. Thereafter, the underfill material 57P is hardened, whereby the underfill layer 57 is obtained (see Chee Choong Kooi and six others, "Capillary Underfill and Mold Encapsulation Materials for Exposed Die Flip Chip Molded Matrix Array Package with Thin Substrate", 2003 Electronics Packaging Technology Conference, pp. 324-330).

**[0008]** However, a level difference locates between the inside and the outside of the opening 56a, and a space over the opening 56a is restricted by the semiconductor chip 53. Therefore, disadvantageously, when the underfill material flows into the opening 56a, air that exists around the periphery of the opening 56a (i.e., exists in a portion having the level difference) is taken into the underfill material without sufficiently going out therefrom, and, as a result, a so-called void 61 is generated in the underfill layer 57. For example, if a void is generated in the underfill layer 57, a crack will appear in the underfill layer 57 at a reflow step, thus causing a decrease in reliability of the semiconductor device.

#### SUMMARY OF THE INVENTION

an object of the present invention to provide a semiconductor device having a structure capable of preventing a void from occurring in a sealing layer.

**[0009]** The semiconductor device according to the present

invention includes a solid state device; a semiconductor chip that has a functional surface on which a functional element is formed and that is bonded on a surface of the solid state device with surface thereof to face a surface of the solid state device while maintaining a predetermined distance between the functional surface thereof and the surface of the solid state device; an insulating film that is provided on the surface of the solid state device facing the semiconductor chip and that has an opening greater in size than the semiconductor chip when the surface of the solid state device facing the semiconductor chip is vertically viewed down in plane; and a sealing layer that seals a space between the solid state device and the semiconductor chip.

**[0010]** According to this invention, the opening of the insulating film is formed to be greater in size than the semiconductor chip when the surface of the solid state device facing the semiconductor chip is vertically viewed down in plane. In other words, the opening of the insulating film is formed such that the semiconductor chip completely falls within the opening when the surface of the solid state device facing the semiconductor chip is vertically viewed down in plane. Therefore, a level difference caused by the opening of the insulating film can be prevented from locating in a gap between the solid state device and the semiconductor chip, and a space over the periphery of the opening can be prevented from being

restricted by the semiconductor chip.

**[0011]** Therefore, in a step of producing this semiconductor device, a void can be prevented from being generated that results from taking air into a liquid sealing resin when a gap between the solid state device and the semiconductor chip is filled with the liquid sealing resin in order to form the sealing layer after forming the insulating film and bonding the solid state device and the semiconductor chip together. As a result, the reliability of the semiconductor device can be improved.

**[0012]** Preferably, the distance between the outer periphery of the semiconductor chip and the edge of the opening of the insulating film is 0.1mm or more when the surface of the solid state device facing the semiconductor chip is vertically viewed down in plane.

**[0013]** The solid state device may be a wiring board formed by being wired on an insulating substrate, or may be a semiconductor substrate.

**[0014]** The insulating film may be a solder resist. In this case, it is possible to prevent an electric short circuit in an area covered with the solder resist.

**[0015]** The sealing layer may be provided in such a way as to fill the inside of the opening therewith. If so, in the solid state device, a part exposed from the opening of the insulating film can be protected with the sealing layer.

**[0016]** The aforementioned object, other objects, features, and

advantageous effects of the present invention will become apparent from the following description of embodiments given with reference to the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic sectional view of a semiconductor device according to a first embodiment of the present invention.

FIG. 2A to FIG. 2D are diagrammatic sectional views for explaining a method for producing the semiconductor device of FIG. 1.

FIG. 3 is a diagrammatic sectional view of a semiconductor device according to a second embodiment of the present invention.

FIG. 4 is a diagrammatic sectional view showing a structure of a conventional semiconductor device that has a semiconductor chip connected in a flip chip manner.

FIG. 5 is a diagrammatic plan view in which a connection surface of a wiring board of FIG. 4 is vertically viewed down.

FIG. 6A and FIG. 6B are diagrammatic sectional views for explaining a method for producing the semiconductor device of FIG. 4.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0017]** FIG. 1 is a diagrammatic sectional view of a semiconductor device according to a first embodiment of the present invention.

**[0018]** This semiconductor device 1 includes a wiring board 2 and a semiconductor chip 3 connected to the wiring board 2 while causing a functional surface 3a of the semiconductor chip 3 to

face a surface 2a of the wiring board 2. A rectangular connection pad (see FIGS. 2C and 2D) is formed on the surface 2a of the wiring board 2. The wiring board 2 and the semiconductor chip 3 are bonded and electrically connected together by means of a connecting member 5 connected to the connection pad, with a predetermined interval between the wiring board 2 and the semiconductor chip 3.

**[0019]** A solder resist film 6 that has a thickness smaller than the interval between the surface 2a of the wiring board 2 and the semiconductor chip 3 is formed on the surface 2a. This solder resist film 6 serves to prevent an electric short circuit from occurring between wires formed on the surface of the wiring board 2. The solder resist film 6 has an opening 6a greater in size than the semiconductor chip 3 when the surface 2a is vertically viewed down in plane. In other words, the solder resist film 6 has an opening 6a large enough to allow the semiconductor chip 3 to completely fall within the opening 6a when the surface 2a is vertically viewed down in plane. Accordingly, the solder resist film 6 does not exist in a gap G between the wiring board 2 and the semiconductor chip 3 (i.e., in an area lying between the wiring board 2 and the semiconductor chip 3 and overlapping with the semiconductor chip 3 when the surface 2a is vertically viewed down in plane).

**[0020]** The distance D between the outer periphery of the semiconductor chip 3 and the edge of the opening 6a of the solder

resist film 6 is set at 0.1mm or more when the surface 2a is vertically viewed down in plane.

**[0021]** An underfill layer 7 is provided in the gap G between the wiring board 2 and the semiconductor chip 3 and in the neighborhood of the gap G. The underfill layer 7 is formed so as to fill the opening 6a of the solder resist film 6 therewith. The underfill layer 7 serves to seal the gap G therewith and to protect the functional surface 3a, the connecting member 5, and an exposed part of the surface 2a exposed from the opening 6a.

**[0022]** An end electrode 8 that is electrically connected to the connecting member 5 through a wire (not shown) is formed at each end of the wiring board 2. The end electrode 8 leads from the surface 2a of the wiring board 2 to an external connection surface 2b which is the surface on the side opposite the surface 2a via the end face. In the end electrode 8, the semiconductor device 1 can establish an electric connection with other wiring boards (mounting boards).

**[0023]** FIGS. 2A to 2D are diagrammatic sectional views for explaining a method for producing the semiconductor device 1 shown in FIG. 1. The semiconductor device 1 can be obtained such that the semiconductor chip 3 is bonded to the wiring board 2 while causing the functional surface 3a of the semiconductor chip 3 to face the surface 2a of the wiring board 2, whereafter an underfill material 7P is injected into the opening 6a of the



solder resist film 6, and the underfill material 7P is hardened, whereby the underfill layer 7 is formed.

**[0024]** In more detail, a substrate 15 in which a plurality of wiring boards 2 are formed is first prepared.

**[0025]** Thereafter, a liquid, photosensitive solder resist film 6 is applied (for example, according to a spin coat method) or is printed onto the whole of a surface 15a of the substrate 15 (i.e., a surface corresponding to the surface 2a of the wiring board 2), and the opening 6a greater in size than the semiconductor chip 3 is formed by exposure and development.

**[0026]** Thereafter, a semiconductor chip 3 having a projection electrode (bump) 18 connected to an electrode of a function element 4 is prepared. The projection electrode 18 includes a solder material.

**[0027]** Thereafter, the substrate 15 is kept substantially horizontal while directing the surface 15a thereof upward. The semiconductor chip 3 is held while the surface opposite the functional surface 3a is being absorbed by a bonding tool 19 equipped with a heater for heating therein. The semiconductor chip 3 is caused to face the surface 15a of the substrate 15 while directing the functional surface 3a downward. FIG. 2A shows this state.

**[0028]** Thereafter, the projection electrode 18 of the semiconductor chip 3 is positionally adjusted for the contact with a connection pad 16 of the substrate 15, whereafter the

bonding tool 19 is lowered so as to bond the semiconductor chip 3 with the substrate 15. In this case, the semiconductor chip 3 is heated by the bonding tool 19, and the solder material of the projection electrode 18 is melted by that heat, whereby the projection electrode 18 and the connection pad 16 are bonded together. As a result, the connecting member 5 by which the substrate 15 and the semiconductor chip 3 are mechanically bonded together is formed. The wiring formed on the surface 15a of the substrate 15 is electrically connected to the function element 4 of the semiconductor chip 3 by means of the connecting member 5.

**[0029]** Thereafter, a dispenser 10 is disposed over the periphery of the opening 6a of the solder resist film 6, whereafter the underfill material 7P is injected from the dispenser 10 into the opening 6a (see FIG. 2B).

**[0030]** The underfill material 7P enters the gap G between the substrate 15 and the semiconductor chip 3, and spreads on the surface 2a in the gap G by capillarity (see FIG. 2C, wherein the direction in which the underfill material 7P spreads is indicated by arrow "A"). The underfill material 7P is discharged from the dispenser 10 by a suitable quantity. When the gap G and the inside of the opening 6a of the solder resist film 6 are filled with the underfill material 7P, the dispenser 10 stops discharging the underfill material 7P. Thereafter, a process for hardening the underfill material 7P is performed, and the

underfill layer 7 is formed in the opening 6a.

**[0031]** Thereafter, the substrate 15 is cut into wiring boards 2 (the cutting position is indicated by reference character "C" in FIG. 2A), and the end electrode 8 is formed at each end of the wiring board 2, thus the semiconductor device 1 of FIG. 1 is obtained.

**[0032]** As described above, the opening 6a of the solder resist film 6 is formed such that the semiconductor chip 3 completely falls within the opening 6a when the surface 15a is vertically viewed down in plane. Accordingly, a level difference caused by the opening 6a of the solder resist film 6 can be prevented from locating in the gap G between the substrate 15 and the semiconductor chip 3, and a space over the periphery of the opening 6a can be prevented from being restricted by the semiconductor chip 3.

**[0033]** Therefore, a void can be prevented from being generated that results from taking air into the underfill material 7P when the liquid underfill material 7P is injected into the gap G between the substrate 15 and the semiconductor chip 3. As a result, the reliability of the thus obtained semiconductor device 1 can be improved.

**[0034]** Since the underfill layer 7 has no void, a crack caused by a void does not occur even when the semiconductor device 1 is bonded with another wiring board according to, for example, a reflow method.

**[0035]** FIG. 3 is a diagrammatic sectional view of a semiconductor device according to a second embodiment of the present invention. In FIG. 3, the same reference character as in FIG. 1 is given to an element corresponding to each element of FIG. 1.

**[0036]** This semiconductor device 21 includes a wiring board 22 and a semiconductor chip 3 connected to the wiring board 22 while causing a functional surface 3a of the semiconductor chip 3 to face a surface 22a of the wiring board 22.

**[0037]** A solder resist film 6 is formed on the surface 22a of the wiring board 22. The solder resist film 6 has an opening 6a that is greater in size than the semiconductor chip 3, in other words, that is formed such that the semiconductor chip 3 completely falls within the opening 6a when the surface 22a is vertically viewed down in plane.

**[0038]** In the wiring board 22, metallic balls 23 are provided on an external connection surface 22b opposite the surface 22a. The metallic balls 23 are re-wired inside the wiring board 22 and/or on the surface of the wiring board 22, and are electrically connected to a connecting member 5 on the side of the surface 22a. The semiconductor device 21 can be bonded with other wiring boards (mounting boards) via the metallic balls 23.

**[0039]** When the semiconductor device 21 is produced, the same producing method as above (see FIGS. 2A to 2D) can be carried out using a substrate on which regions corresponding to a plurality of wiring boards 22 are densely formed, instead of

the substrate 15. The metallic balls 23 may be bonded with this substrate before cutting the substrate into pieces of the wiring board 22, or may be bonded with the wiring boards 22 after cutting the substrate into pieces of the wiring board 22.

**[0040]** Although the embodiments of the present invention have been described as above, the present invention can be embodied in other forms. For example, two or more semiconductor chips 3 may be connected to the wiring boards 2 and 22 in a flip chip manner. In this case, the solder resist film 6 can have at least one opening 6a that completely includes each semiconductor chip 3 when the surfaces 2a and 22a are vertically viewed down in plane.

**[0041]** The embodiments of the present invention have been described in detail. However, these are merely concrete examples used to clarify the technical contents of the present invention, and the present invention should not be understood while being limited to these examples, and the spirit and scope of the present invention are limited only by the scope of the appended claims.

**[0042]** This application claims Paris Convention priority based on Japanese Patent Application No. 2004-282017, filed in Japan Patent Office on September 28, 2004, the entire contents of which are hereby incorporated by reference.